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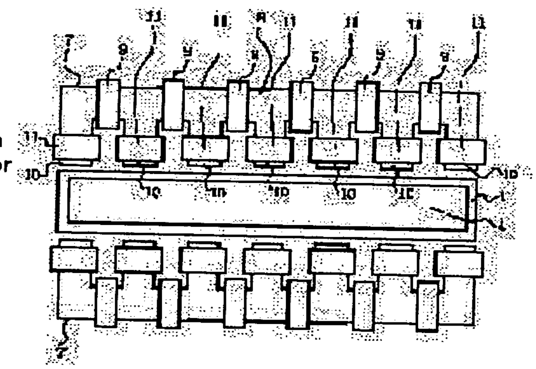
(54) METHOD FOR CONTROLLING FLUIDITY IN MOLD IN CONTINUOUS CASTING AND DEVICE THEREFOR

(57)Abstract:
PROBLEM TO BE SOLVED: To stably execute the reduction of center segregation with increase of equi-axes crystals and the reduction of non-metallic inclusion in a cast slab with the reduction of penetrating depth of spouting flow, etc., in a continuous casting.
SOLUTION: One pair of electromagnets 7 constituted with iron cores 8 interposing a mold 1 and arranged so as to be faced while keeping a fixed interval, plural coils 9 wound on the iron cores, plural magnetic poles 10 branched from the iron cores and plural coils 11 wound on the iron part near the magnetic pole, are set at the lower part of spouting hole of an immersion nozzle so as to conduct the current of DC or AC in the coils. By this method, the molten steel in the mold is stirred by impressing shifting magnetic field in the mold or the molten steel is braked by impressing static magnetic field.



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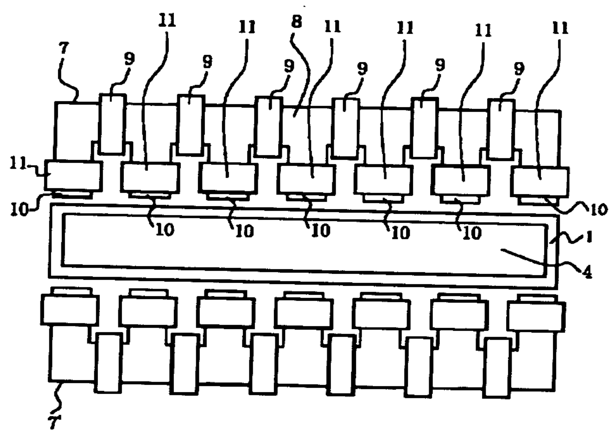
(54)【発明の名称】連続鋳造における鋳型内流動制御方法および装置

(57)【要約】

【課題】　連続鋳造において、等軸晶増加による中心偏析低減や、吐出流の浸透深さ低減による鋳片内の非金属介在物の低減などを安定にかつ安価に行う。

【解決手段】　鋳型１を挟んで、一定の間隔を保って対向配置された鉄芯８、該鉄芯に巻かれた複数のコイル９、鉄芯から枝分かれした複数の磁極１０、および該磁極近くの鉄部分に巻かれた複数のコイル１１から構成される１対の電磁石７を、浸漬ノズルの吐出孔の下部に設置し、コイルに直流や交流の電流を流すことにより、１対の電磁石によって、鋳型内に移動磁場を印加して鋳型内の溶鋼を撹拌したり、または静磁場を印加して溶鋼を制動する。



【特許請求の範囲】

【請求項１】　鋼の連続鋳造において、溶鋼を浸漬ノズルを経て鋳型内へ注湯して鋳片を製造する際、鋳型を挟んで、一定の間隔を保って対向配置された鉄芯、該鉄芯に巻かれた複数のコイル、鉄芯から枝分かれした複数の磁極、および該磁極近くの鉄部分に巻かれた複数のコイルから構成される１対の電磁石を、浸漬ノズルの吐出孔の下部に設置し、コイルに直流または交流の電流を流すことにより、１対の電磁石によって、鋳型内に移動磁場を印加して鋳型内の溶鋼を撹拌したり、または、静磁場を印加して溶鋼を制動することを特徴とする連続鋳造方法。

【請求項２】　連続鋳造用の鋳型を挟んで、一定の間隔を保って対向配置された鉄芯、該鉄芯に巻かれた複数のコイル、鉄芯から枝分かれした複数の磁極、および該磁極の鉄部分に巻かれた複数のコイルから構成される電磁石装置において、電流の種類を直流や３相交流などに切り替えてコイルに電流を流すことにより、１対の電磁石によって、鋳型内に移動磁場を印加したり、または、静磁場を印加することを特徴とする連続鋳造用の電磁石装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、溶鋼の連続鋳造方法に関する。

【０００２】

【従来の技術】鋼の連続鋳造では、一つの連鋳機で種々の鋼種を鋳造する。鋼種の中には、連続鋳造において溶鋼が凝固する際、中心偏析を極力低減する必要があるものや、鋳片内部の非金属介在物を極力低減する必要があるものがある。中心偏析の低減には、鋳型内の溶鋼を電磁撹拌し、等軸晶を増加させることにより、中心偏析を分散・低減できる。一方、鋳片内部の非金属介在物の低減については、鋳型内の溶鋼に静磁場を印加し、浸漬ノズルの吐出孔よりも下方へ流れる下向き流の浸透深さを低減することにより、溶鋼内の介在物が鋳片内部へ捕捉されることを抑制することができる。鋳型部に電磁石装置を設置して溶鋼を撹拌する方法は従来より知られており、特願平４－１３４８９８号公報や特願平４－１５９８０２号公報では鋳型内の溶鋼に移動磁界を印加して撹拌する方法を開示している。また、溶鋼に静磁場を印加し、溶鋼流動を制動する方法は特願昭６２－２４１４３９号公報や特願平４－１２７９３８号公報で開示されている。

【０００３】しかし、溶鋼を撹拌するための電磁石装置と、静磁場の印加により溶鋼を制動するための電磁石装置の二つを鋳型部の同じ場所に設置することは困難であり、また、これら二種類の電磁石装置を近接させて鋳型部に設置することも空間的に困難な場合が多く、仮に可能だとしても設備費用が高くなり、鋳型部に設置した一つの電磁石装置により、連続鋳造する鋼種に応じて溶鋼の撹拌と制動の機能を使い分ける方法が無いのが実状であった。

【０００４】

【発明が解決しようとする課題】一つの連続鋳造機の鋳型部へ設置した一つの電磁石装置によって、鋳型内の溶鋼を撹拌する機能と、鋳型内の溶鋼に静磁場を印加して吐出流の浸透深さを低減する機能を鋼種に応じて使い分けて、等軸晶増加による中心偏析低減や、吐出流の浸透深さ低減による鋳片内の非金属介在物低減を安定にかつ安価に行うことが課題である。

【０００５】

【課題を解決するための手段】本発明者らは、上記課題を解決するために種々検討した結果、電磁石の鉄芯、コイル、磁極の配置や形状に関する工夫と、鉄芯に巻かれた複数のコイルに流す電流の種類を変えることにより、一つの電磁石装置によって、鋳型内の溶鋼に移動磁場を印加して溶鋼を撹拌させたり、静磁場を印加して溶鋼を制動できることを見い出した。また、この一つの電磁石装置を浸漬ノズルの吐出孔の下部に設置することが、撹拌と制動の二つの機能を発揮するのに効果的であることを見いだした。

【０００６】本発明の要旨は、鋼の連続鋳造において、溶鋼を浸漬ノズルを経て鋳型内へ注湯して鋳片を製造する際、鋳型を挟んで、一定の間隔を保って対向配置された鉄芯、該鉄芯に巻かれた複数のコイル、鉄芯から枝分かれした複数の磁極、および該磁極近くの鉄部分に巻かれた複数のコイルから構成される１対の電磁石を、浸漬ノズルの吐出孔の下部に設置し、コイルに直流または交流の電流を流すことにより、１対の電磁石によって、鋳型内に移動磁場を印加して鋳型内の溶鋼を撹拌したり、または、静磁場を誘起して溶鋼を制動することを特徴とする連続鋳造方法である。また、連続鋳造用の鋳型を挟んで、一定の間隔を保って対向配置された鉄芯、該鉄芯に巻かれた複数のコイル、鉄芯から枝分かれした複数の磁極、および該磁極の鉄部分に巻かれた複数のコイルから構成される電磁石装置において、電流の種類を直流や３相交流などに切り替えてコイルに電流を流すことにより、１対の電磁石によって、鋳型内に移動磁場を印加したり、または、静磁場を印加することを特徴とする連続鋳造用の電磁石装置である。

【０００７】

【発明の実施の形態】図１は、連続鋳造において、浸漬ノズル２の吐出孔３を経て溶鋼４を鋳型１の中へ注湯する際、鋳型部に電磁石装置７を設置した時の縦断面図を示す。浸漬ノズルの吐出孔は、通常、水平方向よりも下向きになっており、電磁石装置を作動させない場合、鋳型内へ注湯された溶鋼のノズル吐出流は、鋳片の短片側の凝固シェルに衝突して、ノズルの吐出孔よりも下方へ流れる下向き流と、吐出孔よりも上へ流れる上向き流に

分かれる。溶鋼は鋳型への抜熱により凝固し、凝固シェル6は連続的に下方へ引き抜かれる。下向き流の速度が余りにも大きいと、吐出流の浸透深さが深くなるため、非金属介在物の浮上除去にとって不利となり、鋳片の内部に介在物が多く残り、鋼製品の品質に悪影響を及ぼす。

【0008】鋳型内で溶鋼を電磁撹拌すると、鋳型内の溶鋼温度が低減して浮遊している等軸晶が安定に成長するとともに、凝固シェルやメニスカス近傍において等軸晶の生成が促進され、凝固後の鋳片の中心部における等軸晶領域が多くなる。溶鋼撹拌の強さが強いほど、等軸晶の生成が促進されるが、電磁石による強い撹拌をメニスカス近傍で行うと、鋳造用フラックスを溶鋼中へ巻き込むことになり、品質に悪影響を及ぼす。このため、中心偏析を低減したい鋼種を鋳造する場合、図1に示すように、浸漬ノズルの吐出孔より下方に電磁石を設置し、電磁石装置7を使って溶鋼を撹拌すると、フラックスの巻き込みなどの弊害を招かずに、溶鋼を強く電磁撹拌することができ、等軸晶の増加が容易にでき、中心偏析を分散・低減することが可能である。

【0009】一方、ブリキ製品に使われる低炭アルミキルド鋼などのように鋳片内部の非金属介在物の低減を厳格に行わねばならない鋼種を鋳造する場合、電磁石装置7を使って、溶鋼に静磁場を印加すると、静磁場中を流動する溶鋼に、溶鋼の流動の方向と逆方向へ電磁気力が作用し、溶鋼の流速が低下する。このため、吐出流の浸透深さが大幅に低減し、非金属介在物が溶鋼プールの深い位置まで侵入せず、メニスカスへの浮上除去が促進される。

【0010】図2は、図1のA－Aの位置の水平断面の模式図であり、鋳型1を挟んで一定の間隔を保って対向配置された一対の電磁石7および7’を示す。この電磁石7と7’の構成や機能は同じである。電磁石7は、鉄芯8、鉄芯から枝別れした磁極10、鉄芯に巻かれた複数のコイル9、枝別れした磁極の鉄部分に巻かれたコイル11から構成される。次に説明するように、コイル9や11に流す電流を変えることにより、鋳型内の溶鋼に移動磁界や静磁場を印加することができる。

【0011】移動磁場の印加方法について、図2のコイル11を便宜上省略して示した図3を使って説明する。図3において、隣接した3個のコイルu、v、wに、交流電流の位相を120度づつずらした3相の交流電流を流すと、コイルu、v、wに流す電流の経時変化に応じて、各磁極10の先端から鋳型内の溶鋼に印加される磁界は時間的に変化し、磁極に近い溶鋼に移動磁界が作用することになり、この移動磁界の作用により溶鋼の流れ12が生じる。同様な方法で鋳型の対面側でも溶鋼の流れ12’を生起させることができ、鋳型内の溶鋼が撹拌されることになる。

【0012】溶鋼に静磁場を印加する方法については、2図に示した電磁石装置の場合には、3通りの方法がある。1番目の方法は、コイル11へ直流電流を流す方法であり、コイル11に流す直流電流の向きを任意に変えることにより、図4に示すように、磁極の極性がN極とS極の交互の配置にすることができる。磁界は、N極からS極へ向かうため、鋳型の対面側の磁極の極性をN極とS極の交互の配置とすると、鋳型内の溶鋼にN極からS極へ向かう静磁場が印加でき、この静磁場の中を溶鋼が流動すると、流動の方向と反対側に電磁気力が作用し、溶鋼の流動が抑制される。2番目の方法は、コイル9に2相交流電流を流す際、交流電流の向きを隣接したコイルで交互に変える方法であり、これによって、図4に示すような磁極の極性の配置が得られる。第3の方法は、第2図のコイル11に2相交流電流を流す際、交流電流の向きを隣接したコイルで交互に変える方法であり、これによって、図4に示すような磁極の極性の配置が可能である。

【0013】

【実施例】スラブの連続鋳造において、図2に示すような電磁石装置で鋳型の幅方向に4個の磁極10を有する電磁石装置を鋳型の両側に設置し、移動磁界印加の効果、および静磁場印加の効果を調べる実験を行った。通常の銅鋳型を使った連続鋳造機で、モールドフラックスを用いた鋳造実験において、スラブ鋳片のサイズは厚さ170mm、幅800mmで、鋳型の長さは800mm、ノズル吐出孔の位置はメニスカスから250mm下、鋳造方向における電磁石の中心位置はメニスカスから400mm下になるように設置した。

【0014】まず、炭素濃度が約0．1％の溶鋼の鋳造実験で、鋳型内の溶鋼に移動磁界を印加して、鋳片内部の等軸晶の増加を調査した。移動磁界を印加する図2のコイルへは、3相の交流電流を約500Aを流した。鋳造速度は1m／min、タンディシュにおける溶鋼の注湯過熱度は約30℃であった。鋳造実験後、鋳片内部の凝固組織を調査した結果、鋳片の等軸晶率（すなわち、鋳片の厚さに対する等軸晶帯の厚さの割合）は、移動磁界を印加しない場合に12％、移動磁界を印加した場合には30％となり、移動磁界を印加することにより等軸晶が大幅に増加することが判明した。また、鋳片内の非金属介在物を調査したが、撹拌によるフラックスの巻き込みによる介在物の増加は認められなかった。溶鋼流動の影響下で成長する凝固組織は溶鋼流動の上流側へ傾いて成長するが、鋳片内の凝固組織の傾きを調査し、その傾きの値から溶鋼流速を経験式に基づき推定した結果、最大0．6～0．8m／sの流速があったことが推定された。この様に早い流速でメニスカス付近を撹拌するとフラックスの溶鋼中への巻き込みを助長して、鋳片品質を低下させるが、本発明のようにノズル吐出孔の下部において、早い流速で撹拌すると、鋳造用フラックスの巻き込みを回避して、等軸晶の増加をより効率的に実行で

きる。

【0015】次に、炭素濃度が0．01％のアルミキルド鋼を使って、静磁場印加の実験を行い、鋳造途中に鋳型部の溶鋼中へ硫黄を添加し、鋳造後鋳片内部の硫黄の分布状況に基づいて吐出流の浸透深さを調べるための実験を行った。鋳造速度は1m／minで、溶鋼過熱度は約30℃であった。静磁場印加の条件については、図2のコイル11に直流電流を流すことにより、鋳型内に約0．3テスラの静磁場を発生させた。鋳造実験後の鋳片内部の硫黄分布の調査の結果、静磁場を印加しないと、吐出流の浸透深さは約5．5mであるが、静磁場印加の場合には約3．0mとかなり短くなることが判明した。また、鋳片内部の非金属介在物の調査をスライム抽出法で行った結果、鋼1kg当りに存在する約50μm以上の介在物の個数は、静磁場印加なしの場合、約450個であるが、静磁場を印加すると約250個に減少し、静磁場印加により鋳片品質が向上することが分かった。

【0016】このように、浸漬ノズル吐出孔の下部に設置した一つの電磁石装置を使って、鋼種に応じて溶鋼に移動磁界や静磁場を印加することにより、等軸晶を増加させたり、吐出流の浸透深さを低減して非金属介在物を低減させたりすることが可能であることが分かった。

【0017】

【発明の効果】本発明を実施すれば、中心偏析を低減したい鋼種や非金属介在物を低減したい鋼種の連続鋳造を安定かつ低コストで行うことができる。

【図面の簡単な説明】

【図1】浸漬ノズル、鋳型、電磁石装置の関係を示す縦断面図である。

【図2】図1のA－Aの位置の平面図であり、鋳型を挟んで設置した電磁石装置の模式図である。

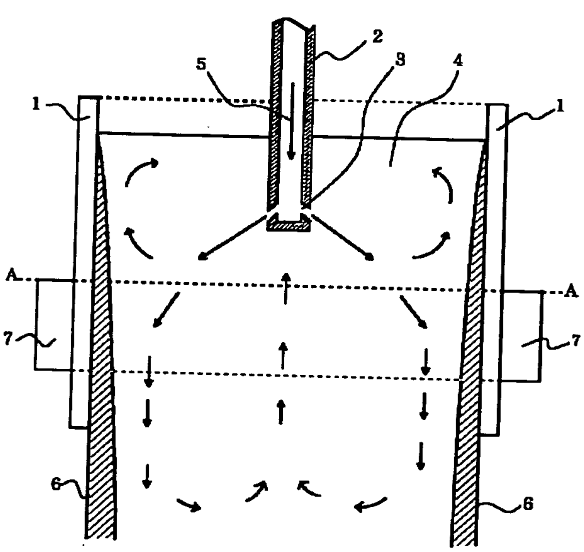
【図3】鋳型を挟んで設置した電磁石装置の模式図である。

【図4】電磁石の磁極の極性が鋳型の両側で交互に対称な場合の模式図である。

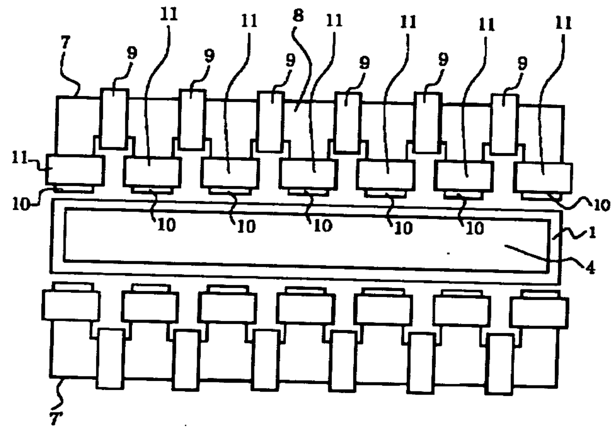
【符号の説明】

1　鋳型
2　浸漬ノズル
3　吐出孔
4　溶鋼
5　溶鋼の流れる方向
6　凝固シェル
7、7'　電磁石
8　鉄芯
9　コイル
10　磁極
11　コイル
12、12'　溶鋼の撹拌方向

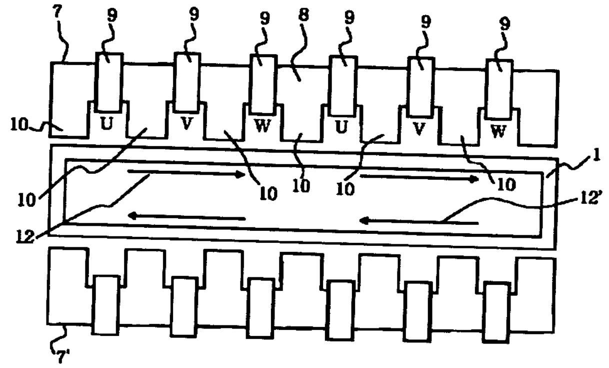
【図1】



【図2】



【図3】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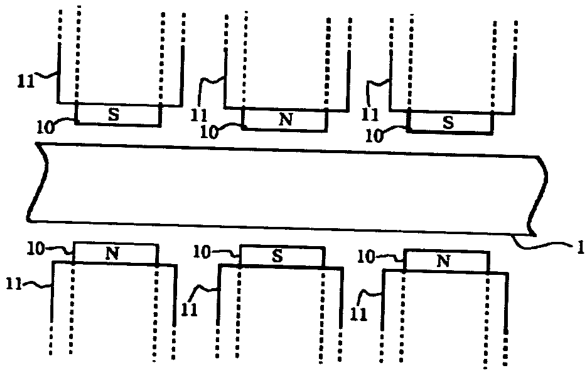
【図4】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Japanese Patent Laid-Open No. 262650/1997
Laid-Open Date : October 7, 1997
Application No. : 97330/1996
Application Date: March 28, 1996
Int. Cl.[6] : B 22 D 11/10, 11/04, 27/02
Inventors : Ken-ichi Miyazawa, Hiroshi Harada and Takashi Moroboshi
Applicant : Nippon Steel Corporation

Title of the Invention: METHOD AND APPARATUS FOR CONTROLLING OF FLOW IN A TEMPLATE IN A CONTINUOUS CASTING

[Abstract]

[Matters to Solve]

In a continuous casting, decrease of center segregation by an increase of isometric crystals and also decrease of nonmetallic inclusion in cast pieces by decrease of depth of penetration of discharge flow are carried out in a stable manner and also at a low cost.

[Solving Means]

A pair of electromagnets 7 constituted from iron cores 8 which are arranged in an opposing manner with predetermined intervals sandwiching a template 1, a plurality of coils 9 wound around the said iron core, a plurality of magnetic poles 10 branched from the iron

core and a plurality of coils 11 wound around an iron part near the said magnetic pole is installed under a discharge hole of the submerged nozzle and electric current such as direct current or alternating current is applied to the coil whereby mobile magnetic field is applied into the template by the pair of magnetic poles to stir the melted steel in the template or static magnetic filed is applied to control the melted steel.

[Claims]

1. A continuous casting method, characterized in that, in the manufacture of cast pieces by pouring the melted steel into a template via a submerged nozzle in a continuous casting of steel, a pair of electromagnets constituted from iron cores which are arranged in an opposing manner with predetermined intervals sandwiching a template, a plurality of coils wound around the said iron core, a plurality of magnetic poles branched from the iron core and a plurality of coils wound around an iron part near the said magnetic pole is installed under a discharge hole of the submerged nozzle and electric current such as direct current or alternating current is applied to the coil whereby mobile magnetic field is applied into the template by the pair of magnetic poles to stir the melted steel in the template or static

magnetic filed is applied to control the melted steel.

2. An electromagnet apparatus for continuous casting, characterized in that, in an electromagnet apparatus constituted from iron cores which are arranged in an opposing manner with predetermined intervals sandwiching a template for a continuous casting, a plurality of coils wound around the said iron core, a plurality of magnetic poles branched from the iron core and a plurality of coils wound around an iron part near the said magnetic pole, the type of electric current is switched to direct current or three-phase alternating current and the current is applied to the coil whereby mobile magnetic field is applied into the template or static magnetic filed is applied by a pair of electromagnets.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a continuous casting method for melted steel.

[0002]

[Prior Art]

In a continuous casting of steel, various kinds of steels are cast in one continuous casting machine. In

some of the steel species, center segregation is to be decreased as much as possible in coagulation of melted steel in the continuous casting while, in others, nonmetallic inclusion inside the cast pieces is to be decreased as much as possible. In decreasing the center segregation, melted steel in the template is electromagnetically stirred and isometric crystals are increased whereby the center segregation can be dispersed and decreased. On the other hand, in decreasing the nonmetallic inclusion inside the cast pieces, static magnetic field is applied to the melted steel in the template and the depth of penetration of the downward flow which flows downstream than the discharge hole of the submerged nozzle whereby trapping of the inclusion in the melted steel inside the case pieces can be suppressed. A method where melted steel is stirred by installing an electromagnetic device in a template part has been known already and, in the Japanese Patent Applications Nos. 134898/1992 and 159802/1992, there is disclosed a method where stirring is carried out by applying mobile magnetic field to the steel in the template. Further, a method where static magnetic field is applied to melted steel to control the flow of the melted steel is disclosed in the Japanese Patent Application Nos. 241439/1987 and 127938/1992.

[0003]

However, it is difficult that an electromagnetic device for stirring the melted steel and an electromagnetic device for controlling the melted steel by application of static magnetic field are placed in the same place of the template part. In many cases, it is also difficult that those two types of electromagnetic devices are placed near and installed in the template because of the space. Even if that is possible, cost for the equipments becomes high and the actual situation is that there is no method where each of functions of stirring and control of the melted steel is properly used depending upon the type of the steel which is continuously cast.

[0004]

[Matter that the Invention is to Solve]

The matter which is to solve is that a function of stirring the melted steel in the template and a function of decreasing the depth of penetration of discharging flow by application of static magnetic field to the melted steel in the template by one electromagnetic device installed in a template part in a continuous casting machine whereby a decrease of center segregation by an increase of isometric crystals and a decrease of nonmetallic inclusion in the cast pieces by decrease of

depth of penetration of discharge flow are carried out in a stable manner and at a low cost.

[0005]

[Means for Solving the Matter]

The present inventors have carried out various investigations for solving the above-mentioned matter and, as a result, they have found that, when arrangement and shape of iron core, coil and magnetic pole of electromagnet are improved and type of electric current applied to a plurality of coils would around the iron core is changed, it is now possible by one electromagnet device to stir the melted steel by application of mobile magnetic field to melted steel in the template and also to control the melted steel by application of static magnetic field. They have further found that installment of the said one electromagnet device below the discharge hole of the submerged nozzle is effective for achieving the two functions of stirring and controlling.

[0006]

The gist of the present invention is a continuous casting method, characterized in that, in the manufacture of cast pieces by pouring the melted steel into a template via a submerged nozzle in a continuous casting of steel, a pair of electromagnets constituted from iron cores

which are arranged in an opposing manner with predetermined intervals sandwiching a template, a plurality of coils wound around the said iron core, a plurality of magnetic poles branched from the iron core and a plurality of coils wound around an iron part near the said magnetic pole is installed under a discharge hole of the submerged nozzle and electric current such as direct current or alternating current is applied to the coil whereby mobile magnetic field is applied into the template by the pair of magnetic poles to stir the melted steel in the template or static magnetic filed is applied to control the melted steel. It is also an electromagnet apparatus for continuous casting, characterized in that, in an electromagnet apparatus constituted from iron cores which are arranged in an opposing manner with predetermined intervals sandwiching a template for a continuous casting, a plurality of coils wound around the said iron core, a plurality of magnetic poles branched from the iron core and a plurality of coils wound around an iron part near the said magnetic pole, the type of electric current is switched to direct current or three-phase alternating current and the current is applied to the coil whereby mobile magnetic field is applied into the template or static magnetic filed is applied by a pair of

electromagnets.

[0007]

[Mode for Carrying Out the Invention]

Fig. 1 shows a longitudinal cross section when an electromagnet device 7 is installed at the template part in case melted steel 4 is poured into a template 1 via a discharge hole 3 of a submerged nozzle 2 in conducting the continuous casting. Usually, the discharge hole of the submerged nozzle is in a downward look from the horizontal direction and, when the electromagnet device is not operated, a discharged flow from the nozzle of the melted steel poured into the template collides against the coagulation shell at the shorter side of the cast piece and divided into a downward flow which flows downward from the discharge hole of the nozzle and a upward flow which flows upward from the discharge hole. Melted steel is coagulated by removal of heat to the template and the coagulation shell 6 is pulled out downward continuously. When the speed of the downward flow is too quick, the depth of penetration of the discharged flow becomes deep and that is disadvantageous to floating and removal of the nonmetallic inclusion whereby much inclusion remains inside the cast piece which badly affects the quality of the steel products.

[0008]

When the melted steel is electromagnetically stirred in the template, temperature of the melted steel in the template lowers and the floating isometric crystals grow in a stable manner and, at the same time, formation of isometric crystals is promoted near the coagulation shell and meniscus and the isometric crystal region in the central area of the cast pieces after coagulation becomes much. The more the stirring strength of the melted steel, the more the promotion of formation of isometric crystals but, when a strong stirring by electromagnet is carried out near the meniscus, the flux for casting is trapped in the melted steel and that badly affects the quality. Therefore, in casting the steel species where the center segregation is to be decreased, the electromagnet is placed below the discharge hole of submerged nozzle as shown in Fig. 1 and the melted steel is stirred using the electromagnet device 7 whereupon a strong electromagnetic stirring of the melted steel without the disadvantage such as trapping of the flux, isometric crystals can be easily increased and center segregation can be dispersed and decreased.

[0009]

On the other hand, when static magnetic field is applied to the melted steel using an electromagnet device

7 in casting the steel species where decrease of nonmetallic inclusion inside the cast pieces is to be strictly carried out such as in the case of low-carbon aluminum-killed steel used for tin plate products, the electromagnetic force acts on the melted steel flowing in the static magnetic field in the direction opposite to the direction of flow of the melted steel whereby the flow rate of the melted steel lowers. As a result, the depth of penetration of the discharged flow greatly decreases, the nonmetallic inclusion does not invade the deep position of the melted steel pool and its removal by floating to the meniscus is promoted.

[0010]

Fig. 2 is a scheme of a horizontal cross section at the position of A-A of Fig. 1 and shows a pair of electromagnets 7 and 7′ which are oppositely placed with a predetermined interval sandwiching the template 1. Constitution and function of those electromagnets 7 and 7′ are same. The electromagnet 7 is constituted from iron core 8, magnetic pole 10 branched from the iron core, a plurality of coils 9 wound around the iron core and coil 11 wound around the iron part of the branched magnetic pole. As will be illustrated hereunder, when the current applied to the coil 9 or 11 is changed, it is possible to apply mobile magnetic field and static

magnetic field to the melted steel in the template.

[0011]

Method for the application of mobile magnetic field is illustrated in Fig. 3 where the coil 11 of Fig. 2 is omitted for the sake of convenience. In Fig. 3, when three-phase alternating current where phases of the alternating current are lagged to an extent of 120° each other is applied to the adjacent coils u, v and w, magnetic field applied to the melted steel in the template from the front end of each magnetic pole 10 changed in terms of time depending upon the change of the current applied to the coils u, v and w with a lapse of time whereupon the mobile magnetic field acts on the melted steel near the magnetic pole and, as a result of action of the said mobile magnetic field, the flow 12 of the melted steel is resulted. By the same method, it is also possible to cause the flow 12′ of the melted steel at the opposite side of the template whereby the melted steel in the template is stirred.

[0012]

With regard to a method for applying the static magnetic field to the melted steel, there are three methods in the case of the electromagnet device as shown in Fig. 2. The first one is a method where direct current is applied to the coil 11 and, when the direction of the

direct current applied to the coil 11 is changed, it is possible as shown in Fig. 4 that polarity of the magnetic pole is made N pole and S pole alternately. The magnetic field comes from N pole to S pole and, therefore, when the polarity of the magnetic pole of the opposite side of the template is made N pole and S pole alternately, static magnetic field from N pole to S pole can be applied to the melted steel in the template and, when the melted steel flows in this static magnetic field, electromagnetic force acts in the direction opposite to the flow direction whereupon flow of the melted steel is suppressed. The second one is a method where, when a two-phase alternating current is applied to the coil 9, direction of the alternating current is changed alternately by the adjacent coil whereby there is obtained the arrangement of polarity of the magnetic pole as shown in Fig. 4. The third one is a method where, when two-phase alternating current is applied to the coil 11 of Fig. 2, direction of the alternating current is alternately changed by the adjacent coil whereby the arrangement of polarity of magnetic pole as shown in Fig. 4 is possible.

[0013]

[Examples]

In a continuous casting of slab, an electromagnet

device having four magnetic poles 10 in the widthwise direction of the template in an electromagnet device as shown in Fig. 2 is placed on both sides of a template and an experiment was carried out for testing the effect of application of mobile magnetic field and the effect of application of static magnetic field. In a casting experiment using a mold flux in a continuous casting machine using a common copper template, size of the slab cast piece was 170 mm thickness and 800 mm width, length of the template was 800 mm, position of the discharge hole of nozzle was 250 mm below the meniscus and the center position of the electromagnet was placed at 400 mm below the meniscus.

[0014]

Firstly, in a casting experiment of melted steel where carbon concentration was about 0.1%, mobile magnetic field was applied to the melted steel in the template and an increase of the isometric crystals in the cast piece was tested. Three-phase alternating current of about 500 A was applied to the coil of Fig. 2 to which mobile magnetic filed was applied. The casting speed was 1 m per minute and superheating degree of pouring melted steel in a tundish was about 30°C. After the casting experiment, coagulated tissues inside the cast piece were checked and, as a result, the

isometric ratio (or, in other words, ratio of the thickness of isometric zone to the thickness of cast piece) was 12% when no mobile magnetic field was applied while, when it was applied, the said ratio was 30% whereupon it was found that the isometric crystals greatly increased when the mobile magnetic field was applied. Further, nonmetallic inclusion in the cast piece was tested but an increase of inclusion by trapping the flux caused by stirring was not noted. Coagulated tissue which grew under the influence of flow of melted steel grew inclining to the upstream side of the flow of melted steel and, when inclination of the coagulated tissue in the cast piece was checked and the flow rate of the melted steel was presumed from the inclined data on the basis of empirical formula, it was presumed that a flow rate of 0.6 to 0.8 m/s at best was available. When stirring is conducted at such a quick flow rate near the meniscus, trapping of the flux into the melted steel is promoted and quality of the cast piece is lowered. However, when stirring is carried out at a high flow rate below the discharge hole of the nozzle as in the present invention, trapping of the flux for casting is avoided whereby an increase of isometric crystals can be carried out efficiently.

[0015]

Then, an experiment of application of static magnetic field was carried out using an aluminum-killed steel where carbon concentration was 0.01%, sulfur was added to the melted steel in the template part during the casting and an experiment was carried out for checking the depth of penetration of discharged flow on the basis of state of distribution of sulfur inside the cast piece after the casting. Casting rate was 1 m per minute and the degree of superheating of the melted steel was about 30°C. With regard to the condition for the application of static magnetic field, direct current was applied to the coil 11 of Fig. 2 whereupon the static magnetic field of about 0.3 Tesla was generated in the template. As a result of investigation of sulfur distribution in the cast piece after the casting experiment, it was found that the depth of penetration of the discharged flow was about 5.5 m when no static magnetic field was applied while, when it was applied, the said depth was considerably shortened to an extent of about 3.0 m. Further, when an investigation of nonmetallic inclusion in the cast piece was carried out by means of a slime extraction method, it was found that numbers of the inclusion of about 50 μm or more existing in each kg of the steel were about 450 when no static magnetic field was applied while, when it was applied, the numbers

decreased to about 250 whereby quality of the cast piece was improved by application of static magnetic field.

[0016]

When mobile magnetic field or static magnetic field is applied to melted steel depending upon the type of the steel using one electromagnet device placed below the discharge hole of submerged nozzle as such, it has now been found that isometric crystals are increased or depth of penetration of discharged flow is decreased whereupon nonmetallic inclusion is decreased.

[0017]

[Advantages of the Invention]

When the present invention is carried out, it is possible to conduct a continuous casting of the steel type which is aimed to decrease the center segregation or to decrease the nonmetallic inclusion in a stable manner and at a low cost.

[Brief Description of the Drawings]

Fig. 1 is a longitudinal cross section showing the relation among submerged nozzle, template and electromagnet device.

Fig. 2 is a plain view of the position of A-A of Fig. 1 and is a scheme of an electromagnet device installed by sandwiching a template.

Fig. 3 is a scheme of an electromagnet device installed by sandwiching a template.

Fig. 4 is a scheme when polarity of magnetic pole of the electromagnet is symmetric alternately at both sides of the template.

[Explanation of the symbols]

1	template
2	submerged nozzle
3	discharging hole
4	melted steel
5	direction of flow of the melted steel
6	coagulation shell
7, 7'	electromagnets
8	iron core
9	coil
10	magnetic pole
11	coil
12, 12'	direction of stirring of melted steel